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Total dietary fiber intakes in the US population are related to whole grain consumption: results from the National Health and Nutrition Examination Survey 2009 to 2010☆

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ABSTRACT

determine whether associations exist between WG intake (no-WG intake, 0 ounce equivalent [oz eq]; low, >0-<3 oz eq; high, ≥3 oz eq) and total dietary fiber intake among Americans 2 years and older. One-day food intake data from the US National Health and Nutrition Examination Survey 2009 to 2010 (n = 9042) showed that only 2.9% and 7.7% of children/adolescents (2-18 years) and adults (≥19 years) consumed at least 3 WG oz eq/d, respectively. For children/adolescents and adults, individuals in the high WG intake group were 59 and 76 times more likely to fall in the third fiber tertile, respectively, compared with those with no-WG intake. Total dietary fiber intake from food sources varied by WG intake group for children/adolescents and adults with more total dietary fiber consumed from ready-to-eat (RTE) and hot cereals and yeast breads/rolls in the high WG intake group compared with the no-WG intake group. Major WG sources for children/adolescents and adults included yeast bread/rolls (24% and 27%, respectively), RTE cereals (25% and 20%, respectively), and oatmeal (12% and 21%, respectively). Among those with the highest WG intake, WG RTE cereal with no added bran was the greatest contributor to total dietary fiber compared with other RTE cereal types. Whole grain foods make a substantial contribution to total dietary fiber intake and should be promoted to meet recommendations.

1. Introduction

Evidence from a meta-analysis of longitudinal studies among adults indicated an association between whole grain (WG) intake and reduced risk of type 2 diabetes, cardiovascular disease, and overweight [1]. Whole grain intake among school-aged children (third-sixth grades) and female adolescents was associated with lower body mass index z-scores and

Abbreviations: NCHS, National Center for Health Statistics; NHANES, National Health and Nutrition Examination Survey; NSLP, National School Lunch Program; oz eq, ounce equivalent; RTE, ready-to-eat; USDA, US Department of Agriculture; WG, whole grain.

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lower risk of overweight in young adulthood, respectively [2,3]. The protective health benefits of WG have been attributed to numerous components including total dietary fiber and bioactive compounds in bran and germ such as vitamins, minerals, trace elements, polyphenols, alkylresorcinols, and carotenoids [4-7].

US Dietary Guideline recommendations indicate that at least half of all grains be consumed as WGs [8], which typically includes at least 3 ounce equivalents (oz eq)/d for adults and 1.5 to 4 oz eq/d for children/adolescents, depending on age, sex, and energy needs [8]. However, US National Health and Nutrition Examination Survey (NHANES) 1999 to 2004 data showed that only 1.5% to 4.3% of children/adolescents, 4.8% of adults aged 19 to 50 years, and 6.6% of adults aged 51+ years consumed at least 3 WG oz eq/d [9,10]. Most children/adolescents and adults also do not consume the recommended grams/day of total dietary fiber [11]. Adequate Intake (AI) values of 19 to 25 g/d were established for children aged 1 to 8 years, 31 to 38 g/d for boys aged 9 to 18 years, 26 g/d for girls aged 9 to 13 years, and 21 to 38 g/d for women and men 19 years or older from Dietary Reference Intakes [12]. Based on data from NHANES 2003 to 2006, less than 3% of children/adolescents had a usual fiber intake that was greater than the AI [11]. Dietary fiber intakes for adults were also less than the AI, with mean intakes of 13.7 g/d and 17.6 g/d for women and men (age, ≥19 years), respectively [11].

The top food sources of WG based on NHANES 2001 to 2002 data for all persons 2 years and older included ready-to-eat (RTE) cereals (28.7%), yeast breads (25.3%), hot cereal (13.7%), and popcorn (12.4%) [13]. However, the release of the 2005 Dietary Guidelines and accompanying media attention has increased consumer demand for WG foods [14] and resulted in greater WG food availability [15]. Results from a US national survey in 2012 [16] indicated that WG and fiber content were top considerations when buying packaged foods for 67% and 62% of consumers, respectively. Given the greater visibility of WG recommendations since 2005 and increased consumer demand, an updated assessment of WG sources, intake, and relationship to total dietary fiber is needed.

The 2010 Dietary Guidelines for Americans recommended an increased intake of WG and total dietary fiber [8] based on low current intakes, reported associations with lower chronic disease risk, risk indicators and overweight [1,17-20], and higher overall diet quality [9,10,21]. Cooked dry beans and peas, other vegetables, fruit, and WG were recommended as food sources to meet total dietary fiber recommendations [8]. Previous studies have suggested that consumers associate WG foods with fiber and may be confused regarding the difference between WG and total dietary fiber [22-24].

Clarification of the contribution that WG foods make to total dietary fiber based on the most recent dietary intake data will allow educators to promote WG foods for the array of nutritional benefits that are provided, including total dietary fiber. The purpose of this study was to test the hypothesis that associations exist between WG intake and total dietary fiber intake of Americans 2 years and older. In addition, the contribution of various food sources to WG intake was identified. Specific research objectives were to (1) determine whether associations exist between WG intake group (no-WG intake, 0 oz eq; low, >0-<3 oz eq; high, ≥3 oz eq) and total dietary fiber intake among children and adolescents (age, 2-18 years) and adults (age, ≥19 years) by examining the odds of falling into a specific WG intake group by total dietary fiber intake tertile, (2) to determine if total dietary fiber intake from various food sources differs by WG intake, (3) to determine if the percentage of total dietary fiber contributed by types of RTE cereal varies by WG intake, and (4) to identify the contribution of different food sources to WG intake.

2. Methods and materials

2.1. *Study population*

Data from NHANES 2009 to 2010 were used for the present analysis [25]. The continuous NHANES is a cross-sectional survey that collects data about the nutrition and health status of the US population using a complex, multistage, probability sampling design [25]. National Health and Nutrition Examination Survey is conducted in a noninstitutionalized, civilian US population by the National Center for Health Statistics (NCHS). Participants of NHANES completed a comprehensive questionnaire assessing dietary behaviors, health history, socioeconomic status, and demographic information at NHANES Mobile Examination Centers and in participant's homes. The NCHS Research Ethics Review Board reviewed and approved all study protocols for NHANES 2009 to 2010. Owing to the nature of the analysis (secondary data analysis) and the lack of personal identifiers, this study was exempted by the University of Minnesota Institutional Review Board.

2.2. *Dietary intake assessment*

Trained interviewers conducted in-person 24-hour dietary recalls using the US Department of Agriculture's (USDA's) Automated Multiple-Pass Method 5-step data collection [25]. Dietary data included detailed descriptions of all food and quantities eaten. Detailed descriptions of the dietary interview methods are provided in the NHANES Dietary Interviewer's Training Manual, which includes pictures of the Computer-Assisted Dietary Interview system screens, measurement guides, and charts used to collect dietary information [25].

Two days of dietary intake were collected from participants. Dietary intake data for the first day were collected through in-person interview and used for analysis in this study. Participants with complete and reliable dietary data were included, as determined by the NCHS. US Department of Agriculture's Food and Nutrient Database for Dietary Studies was used to code and estimate the nutrient content of reported food and beverages [26].

2.3. *Whole grain and fiber content*

The MyPyramid Equivalents Database for USDA Survey Food Codes, version 2.0A, was used in NHANES 2009 to 2010 to calculate WG intake [27]. A Center for Nutrition Policy and Promotion addendum to MyPyramid Equivalents Database 2.0A was used to estimate WG intake from 117 new food codes from NHANES 2005 to 2006 and 2007 to 2008 [28]. Whole grain values were imputed for 96 new food codes from NHANES 2009 to 2010 based on the reported content of similar foods.

The MyPyramid Equivalents Database is currently the only database available that provides quantified measures of WG foods with separate tables based on the old and new (without bran) definitions for WG. My Pyramid Equivalents food data files contain the number of servings (oz eq) per 100 g of food for 32 MyPyramid food groups, 3 of which are WG, non-WG, and total grain. Examples of WG food servings contained within the database include 1 slice of 100% WG bread, 1 cup of 100% WG cereal, or one-half cup of 100% WG hot cereal, cooked pasta, rice, or other grain such as bulgur, oatmeal, and whole cornmeal. Total dietary fiber is a reported variable in NHANES based on values reported in USDA's Food and Nutrient Database for Dietary Studies.

2.4. *Population categorization*

The NHANES 2009 to 2010 was used in this secondary analysis to examine the relationship between WG and total dietary fiber intake among children and adolescents (2-18 years of age; n = 3124) and adults (≥19 years of age; n = 5918). Participants were categorized into 1 of 3 WG intake groups based on oz eq consumed per day: none or no WG (0 oz eq/d), low (>0 to <3 oz eq/d), and high (≥3 oz eq/d). This categorization was chosen based on the recommendation that most Americans consume at least half of all grains as WG or 3 oz eq/d [8].

Furthermore, the study populations were divided into tertiles based on total dietary fiber intake (in g/d): for adults (<11.6, 11.6-19.2, >19.2) and children and adolescents (<9.6, 9.6-15.4, >15.4). The percentage of individuals among different fiber tertiles was then assigned to the corresponding WG group.

2.5. *Food group analysis*

The food sources of total dietary fiber were calculated for children/adolescents and adults and reported by WG intake group. Because RTE cereals are a primary source of WG, the percentage of fiber contributed by RTE cereals was calculated by the WG intake group. Categories of RTE cereals included WG with added bran, WG with no added bran, non-WG with added bran, and non-WG with no added bran.

2.6. *Statistical analyses*

All statistical analyses were performed with SAS 9.2 (SAS Institute, Cary, NC, USA). Dietary intake sample weights were applied to all analyses to account for the unequal probability of selection, noncoverage, and nonresponse bias resulting from oversampling of low-income persons, adolescents, elderly persons, African Americans, and Mexican Americans. Demographic, socioeconomic, and physical activity information was obtained from their respective NHANES questionnaires. Mean ± SEs for WG (in oz eq/d; Table 1) and total dietary fiber intake (in g/d; Tables 2-4) were calculated using PROC SURVEYMEANS, whereas the percentage of individuals per WG intake group and per WG intake group by fiber tertile (Tables 1 and 2) was calculated using PROC SURVEYFREQ. Analysis of variance (ANOVA) was performed using the SURVEYREG procedure to determine if total dietary fiber intake differed across WG intake groups by fiber tertile and within the same tertile by WG intake group (Table 2). Multinomial logistic regression was performed to compare odds of falling in different WG intake groups among different total dietary fiber intake tertiles (Table 2). Mean intake from each food source was divided by total intake to calculate percent contribution of fiber from different food sources using PROC SURVEYMEANS (Table 3). Similarly, mean fiber intake from different RTE cereals was calculated using PROC SURVEYMEANS (Table 4). Analysis of variance was used to determine if total dietary fiber differed for various food sources and RTE cereal type by WG intake group (Tables 3 and 4). Mean intake from each WG food source was divided by total WG intake to calculate percent contribution of WG from different food sources using PROC SURVEYMEANS (Fig.). A *P* value of .05 or less was considered statistically significant.

3. Results

Approximately half of children/adolescents (49.9%) and adults (51.7%) were female. Most children/adolescents and adults were non-Hispanic white (57.7% and 68.3%, respectively), whereas 11.6% to 21.4% of children/adolescents or adults were African American or Hispanic.

Table 1 presents WG intake for all children/adolescents and adults and by WG intake group. A high percentage of children/adolescents (38.8%) and adults (41.9%) consumed no WG, whereas most children/adolescents (58.3%) and adults (50.4%) consumed a small amount (>0-<3 oz eq/d), and only a few children/adolescents (2.9%) and adults (7.7%) consumed at least 3 oz eq/d. Mean daily WG intake was 0.57 (±0.02) oz

Table 1 – Whole grain intake for all children/adolescents (age, 2-18 years) and adults (age, ≥19 years) and by WG intake group

	All	WG intake group		
		None (0 oz eq/d)	Low (>0-<3 oz eq/d)	High (≥3 oz eq/d)
Children/adolescents	n = 3124	n = 1321	n = 1720	n = 83
Mean ± SE [a]	0.57 ± 0.02	0.0 ± 0.0	0.79 ± 0.02	3.99 ± 0.10
Percentage [b]	100.0	38.8	58.3	2.9
Adults	n = 5918	n = 2677	n = 2853	n = 388
Mean ± SE	0.82 ± 0.03	0.0 ± 0.0	0.96 ± 0.03	4.38 ± 0.09
Percentage	100.0	41.9	50.4	7.7

[a] Values represent mean ± SE for WG intake in oz eq/d.
[b] Values represent percent of total individuals in each group.

Table 2 – Whole grain intake and percentage of children/adolescents (age, 2-18 years) and adults (age, ≥19 years) for fiber tertile by WG intake group and odds of falling into different WG intake groups by fiber tertile

Fiber tertile (mean g ± SE, range [g]) [1]	WG intake group								
	None (0 oz eq/d)			Low (>0-<3 oz eq/d)			High (≥3 oz eq/d)		
	Mean ± SE [2]	% [3]	Odds ratio (95% CL) [4]	Mean ± SE	%	Odds ratio (95% CL)	Mean ± SE	%	Odds ratio (95% CL)
Children/adolescents	n = 1321			n = 1720			n = 83		
1 (6.9 ± 0.1, <9.6)	0.0 ± 0.0^{a} [5]	16.3	1.0	0.53 ± 0.03^{bx} [6]	16.1	1.0	3.51 ± 0.39^{cx}	0.1	1.0
2 (12.2 ± 0.06, 9.6-15.4)	0.0 ± 0.0^{a}	12.8	1.0	0.76 ± 0.04^{by}	20.9	1.65 (1.25-2.18)	3.88 ± 0.17^{cx}	0.4	7.39 (1.6-32.5)
3 (21.7 ± 0.3, >15.4)	0.0 ± 0.0^{a}	9.7	1.0	1.01 ± 0.05^{bz}	21.2	2.21 (1.59-3.07)	4.02 ± 0.12^{cx}	2.4	58.7 (12.8-269)
Adults	n = 2677			n = 2853			n = 388		
1 (7.8 ± 0.07, <11.6)	0.0 ± 0.0^{a}	20.2	1.0	0.66 ± 0.04^{bx}	12.9	1.0	3.63 ± 0.30^{cx}	0.2	1.0
2 (15.2 ± 0.08, 11.6-19.2)	0.0 ± 0.0^{a}	12.9	1.0	0.93 ± 0.04^{by}	19.2	2.32 (2.0-2.7)	3.94 ± 0.16^{cy}	1.6	13.67 (5.8-32.5)
3 (28.1 ± 0.30, >19.2)	0.0 ± 0.0^{a}	8.8	1.0	1.21 ± 0.04^{bz}	18.3	3.25 (2.7-3.9)	4.52 ± 0.09^{cy}	5.9	75.95 (32.6-177.2)

[1] Values represent mean total dietary fiber intake as grams/day ± SE and intake range in grams for each fiber tertile calculated using PROC SURVEYMEANS.
[2] Values represent mean WG intake as ounce equivalents per day ± SE by WG intake group calculated using PROC SURVEYMEANS.
[3] % represents the proportion of individuals in each fiber tertile by WG intake group calculated using PROC SURVEYFREQ.
[4] Odds ratio (95% CL) represents the odds of falling in different WG intake groups among different fiber tertiles and 95% confidence limits. Odds ratios are estimated for second and third fiber tertiles and low and high WG intake groups, keeping the first fiber tertile and no (none)-WG intake group as a reference according to multinomial logistic regression analyses.
[5] WG intake within the same fiber tertile with different superscript letters (^{a,b,c}) are significantly different ($P < .05$) according to ANOVA performed using SURVEYREG procedure.
[6] Mean WG intake within the same WG intake group with different superscript letters (^{x,y,z}) are significantly different ($P < .05$) according to ANOVA performed using SURVEYREG procedure.

eq/d for all children/adolescents and 0.82 (±0.03) oz eq/d for all adults. Those children/adolescents and adults in the low intake group (>0-<3 oz eq/d) consumed 0.79 (±0.02) and 0.96 (±0.03) oz eq/d, respectively.

The percentage of children/adolescents and adults in each total dietary fiber tertile by WG intake groups is presented in Table 2. For each fiber tertile for children/adolescents and adults, WG intake was greater among those in the low and high intake groups compared with the no-WG intake group and among those in the high groups compared with the low groups. For the low WG intake groups, WG intake was significantly higher from the first to third fiber tertiles (from 0.53 to 1.01 oz eq/d for children/adolescents and from 0.66 to 1.21 oz eq/d for adults). For the high WG intake groups, WG intake did not differ for children/adolescents from the first to third tertiles; however, for adults, WG intake was lower for the first fiber tertile (3.63 oz eq/d) compared with the second tertile (3.94 oz eq/d) and third tertile (4.52 oz eq/d). For children/adolescents and adults, individuals in the high WG intake group were 59 and 76 times more likely to fall in the third fiber tertile, respectively, compared with those with no-WG intake.

Total dietary fiber intake from various food groups by WG intake group is presented in Table 3. Total dietary fiber intake was significantly greater for those in the high WG group compared with the low and no-WG intake groups among both children/adolescents and adults. For children/adolescents and adults, fiber intake was greater from yeast bread/rolls, crackers and salty grain snacks, hot cereals, and RTE cereals for those in the low and high WG groups compared with the no-WG group. For adults, fiber intake was also greater from cakes/cookies/pies/pastries, grain mixtures/frozen plate meals/soups/meat substitutes, and fruits for those in the low and high WG groups compared with the no-WG group.

Children/adolescents and adults with a WG intake of at least 3 oz eq/d had total dietary fiber intakes of 24.5 and 28.0 g/d, respectively (Table 3). For children/adolescents in the high WG intake group (≥3 oz eq), the food groups contributing the most total dietary fiber to the diet included grain mixtures/frozen plate meals/soups/meat substitutes (16.2%), RTE cereals (11.0%), and fruits (10.3%). For children/adolescents with no-WG intake, the food group sources contributing the most total dietary fiber to the diet included grain mixtures/frozen plate meals/soups/meat substitutes (21.6%), vegetables (16.2%), and fruits (13.7%). The greatest contributors to total dietary fiber intake for adults in the high WG intake group were fruits (15.6%), vegetables (14.5%), yeast bread/rolls (11.9%), and RTE cereals (10.7%). For adults with no-WG intake, food sources making the greatest contribution to total dietary fiber intake included vegetables (23.7%), grain mixtures/frozen plate meals/soups/meat substitutes (16.2%), fruits (12.9%), and dry beans/peas/legumes (11.7%).

Major WG sources for children/adolescents included RTE cereals (25%), yeast bread/rolls (24%), oatmeal (12%), and popcorn (12%) (Fig.). For adults, major WG sources included yeast bread/rolls (27%), oatmeal (21%), RTE cereals (20%), and popcorn (9%).

There were a total of 219 individual RTE cereal brands in USDA's Food and Nutrient Database for Dietary Studies v5.0 that were included in the analysis [26]. This generally reflects the marketplace at the time of collection. Of those brands, 42% were classified as WG with no added bran, 38% were non-WG with no added bran, and 10% were both WG with added bran and non-WG with added bran. Most brands consumed were classified as non-WG with no added bran followed by WG with no added bran. Table 4 presents the percentage of total dietary fiber contributed by RTE cereal brands that are either WG or non-WG and with or without added bran by WG intake group.

Table 3 – Sources of daily total dietary fiber intake for children/adolescents (age, 2-18 years) and adults (age, ≥19 years) by WG intake group

Food category	Total		WG Intake Group					
			None (0 oz eq)		Low (>0-<3 oz eq)		High (≥3 oz eq)	
	Mean (g) [1]	% Fiber contribution [2]	Mean (g)	% Fiber contribution	Mean (g)	% Fiber contribution	Mean (g)	% Fiber contribution
Children/Adolescents	n = 3124		n = 1321		n = 1720		n = 83	
Yeast breads, rolls	1.3	9.5	0.9[a,3]	7.2	1.5[b]	10.9	2.1[b]	8.5
Quick breads	0.4	3.3	0.5[a]	3.8	0.4[a]	2.9	1.1[a]	4.5
Cakes, cookies, pies, pastries [4]	0.6	4.2	0.5[a]	4.2	0.6[b]	4.5	0.6[ab]	2.3
Crackers and salty grain snacks	0.9	6.3	0.5[a]	4.3	1.0[b]	7.3	2.1[c]	8.7
Pancakes, waffles, French toast, crepes	0.3	1.9	0.2[a]	1.5	0.3[b]	2.3	0.3[ab]	1.1
Pastas, macaroni, rice	0.2	1.2	0.1[a]	1.0	0.2[a]	1.2	0.6[b]	2.5
Hot cereals	0.1	0.9	0.0[a]	0.1	0.1[b]	0.6	2.2[c]	8.9
RTE cereals	0.9	6.8	0.5[a]	4.2	1.1[b]	7.9	2.7[b]	11.0
Grain mixtures, frozen plate meals, soups, meat substitutes [5]	2.4	17.8	2.6[ab]	21.6	2.2[a]	15.7	4.0[b]	16.2
Dry beans, peas, legumes, nuts and seeds	0.9	6.3	0.7[a]	5.7	0.9[a]	6.5	2.0[a]	8.1
Fruits	2.0	14.9	1.7[a]	13.7	2.2[b]	15.9	2.5[ab]	10.3
Vegetables	1.9	13.7	2.0[a]	16.2	1.8[a]	12.7	2.3[a]	9.3
All other foods	1.8	13.2	2.0[a]	16.5	1.7[b]	11.7	2.1[ab]	8.6
Total	13.6	100.0	12.1[a]	100.0	14.1[b]	100.0	24.5[c]	100.0
Adults	n = 5918		n = 2677		n = 2853		n = 388	
Yeast breads, rolls	1.7	10.0	1.0[a,3]	7.3	2.0[b]	11.3	3.3[c]	11.9
Quick breads	0.7	3.9	0.8[a]	5.6	0.5[b]	2.7	1.0[a]	3.7
Cakes, cookies, pies, pastries [4]	0.6	3.8	0.5[a]	3.3	0.8[b]	4.4	0.7[b]	2.6
Crackers and salty grain snacks	0.7	4.1	0.3[a]	2.3	0.8[b]	4.7	1.8[c]	6.4
Pancakes, waffles, French toast, crepes	0.1	0.7	0.0[a]	0.4	0.2[b]	1.0	0.2[ab]	0.6
Pastas, macaroni, rice	0.2	1.1	0.1[a]	1.0	0.2[a]	0.9	0.6[b]	2.2
Hot cereals	0.3	1.9	0.0[a]	0.3	0.2[b]	1.3	2.5[c]	8.8
RTE cereals	1.1	6.4	0.2[a]	1.5	1.5[b]	8.6	3.0[c]	10.7
Grain mixtures, frozen plate meals, soups, meat substitutes [5]	2.1	12.1	2.3[a]	16.2	1.9[b]	10.9	1.7[b]	6.1
Dry beans, peas, legumes, nuts and seeds	1.7	10.1	1.6[a]	11.7	1.6[a]	9.1	2.7[b]	9.5
Fruits	2.4	14.2	1.8[a]	12.9	2.6[b]	14.8	4.4[c]	15.6
Vegetables	3.4	20.1	3.3[a]	23.7	3.4[a]	19.1	4.1[b]	14.5
All other foods	2.0	11.7	2.0[a]	13.9	2.0[a]	11.2	2.1[a]	7.5
Total	17.0	100.0	14.1[a]	100.0	17.8[b]	100.0	28.0[c]	100.0

[1] Values represent mean total dietary fiber intake as grams/day calculated using PROC SURVEYMEANS.
[2] Values represent the percentage daily contribution to total dietary fiber intake for all individuals and by WG intake group calculated using PROC SURVEYFREQ.
[3] Means within the same row with different letters ([a,b,c]) are statistically significantly different ($P < .05$) according to ANOVA performed using SURVEYREG procedure.
[4] Includes cereal bars.
[5] Examples include pasta, pizza, soups (eg, containing noodles or rice), egg rolls, and pizza rolls.

For children/adolescents and adults with ≥3 oz eq/d WG intake, WG cereals with no added bran accounted for the largest portion of RTE cereal's total dietary fiber contribution (6.7% or 1.64 g/d and 6.2% or 1.73 g/d, respectively). For children/adolescents in the low WG intake group, non-WG cereals with no added bran accounted for 2.2% of total dietary fiber (0.30 g/d). For adults in the low WG intake group, non-WG cereals with added bran accounted for 2.3% of total fiber intake (0.40 g/d). For children/adolescents and adults who did not consume any WG, non-WG cereals with no added bran accounted for 2.9% (0.35 g/d) and 0.8% (0.11 g/d) total dietary fiber intake, respectively. Total dietary fiber intake from WG with no added bran cereals and from all RTE cereals was greater for children/adolescents and adults in the low and

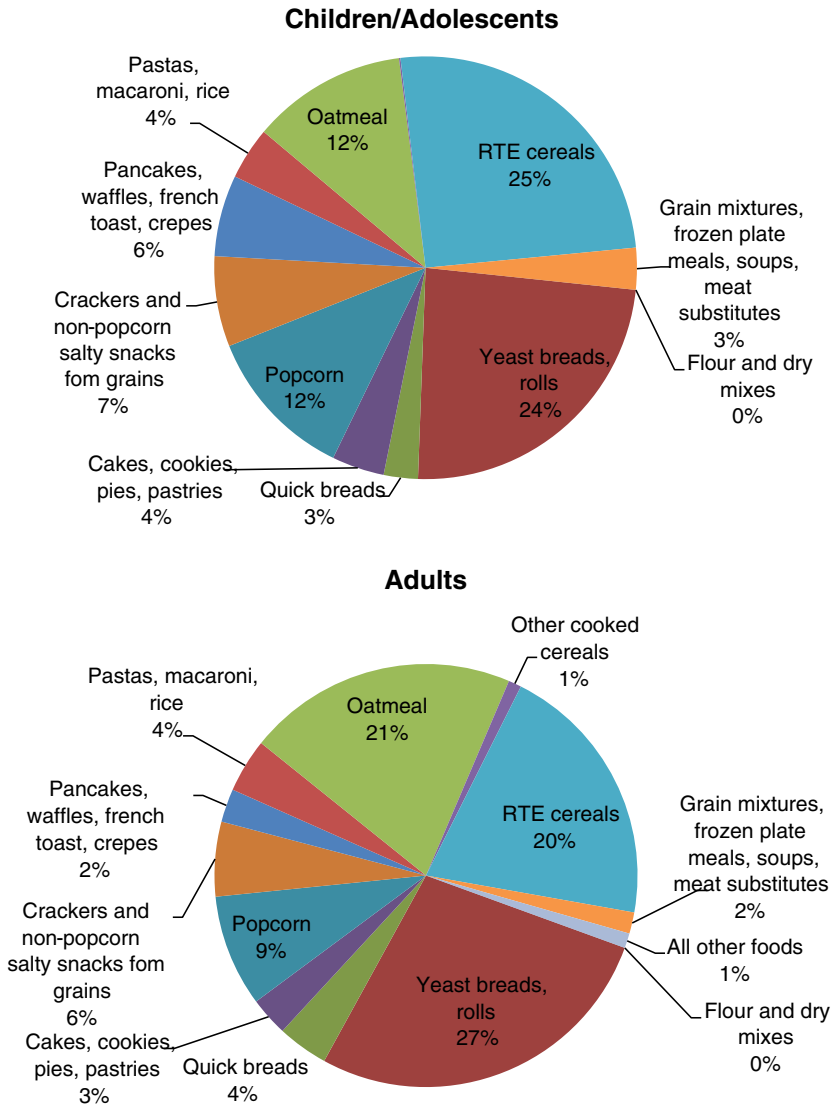

Fig – Whole grain food sources for children/adolescents (age, 2-18 years) and adults (age, ≥19 years) from the NHANES 2009 to 2010.

high WG intake groups compared with those in the no-WG intake groups.

4. Discussion

The primary hypothesis that associations exist between WG intake and total dietary fiber intake of Americans 2 years and older was accepted. Nationally representative data from NHANES 2009 to 2010 showed that both children/adolescents and adults who consumed at least 3 oz eq/d WG were more likely to be in the highest tertile of total dietary fiber intake, whereas those with no-WG intake were more likely to be in the lowest tertile. These findings are consistent with previous studies based on NHANES data (1999-2004) showing that for children (6-12 years), adolescents (12-19 years), and adults, higher WG consumption was associated with higher total dietary fiber intake [9,10,17,29]. A national survey of children and teens in Ireland also showed a positive association between WG intake and total dietary fiber intake [30].

US Department of Agriculture nutrient profiles for food groups in the MyPyramid Equivalents Database [31] indicate that WG choices can account for about 28% of the total dietary fiber recommendation. However, in the current study, only a small proportion of children/adolescents and adults consumed at least 3 oz eq/d WG; hence, other foods accounted for a larger proportion of total dietary fiber intake for most of the sample. For example for children and adolescents, fruits and vegetables provided about one-third of the total dietary fiber intake for those who consumed less than 3 oz eq/d WG and only about one-fifth for those who consumed at least 3 oz eq/d WG. Similarly, for a nationally representative sample of children/adolescents and adults (NHANES 2003-2006), others have found that about one-third of total dietary fiber intake was provided by fruit and vegetable food sources [32,33]. Dividing the total sample into WG intake groups in the current

Table 4 – Mean fiber intake and percentage fiber contributed by RTE cereal types for children/adolescents (age, 2-18 years) and adults (age, ≥19 years) by WG intake group

RTE cereal category [1]	All		WG intake group					
	g/d [2]	% Fiber contribution [3]	None (0 oz eq)		Low (>0-<3 oz eq)		High (≥3 oz eq)	
			g/d	% Fiber contribution	g/d	% Fiber contribution	g/d	% Fiber contribution
Children/Adolescents		n = 3124		n = 1321		n = 1720		n = 83
WG with added bran	0.04	0.3	0.00[a,4]	0.0	0.07[b]	0.5	0.00[a]	0.0
WG with no added bran	0.43	3.1	0.00[a]	0.0	0.65[b]	4.6	1.64[b]	6.7
Non-WG with added bran	0.12	0.9	0.16[a]	1.3	0.08[a]	0.6	0.36[a]	1.5
Non-WG with no added bran	0.33	2.4	0.35[a]	2.9	0.30[a]	2.2	0.69[a]	2.8
All cereals	0.93	6.8	0.51[a]	4.2	1.11[b]	7.9	2.69[b]	11.0
Adults		n = 5918		n = 2677		n = 2853		n = 388
WG with added bran	0.15	0.9	0.00[a]	0.0	0.25[b]	1.4	0.29[ab]	1.0
WG with no added bran	0.49	2.9	0.01[a]	0.1	0.71[b]	4.0	1.73[c]	6.2
Non-WG with added bran	0.30	1.8	0.09[a]	0.6	0.40[b]	2.3	0.84[b]	3.0
Non-WG with no added bran	0.15	0.9	0.11[a]	0.8	0.18[b]	1.0	0.14[ab]	0.5
All cereals	1.09	6.4	0.21[a]	1.5	1.54[b]	8.6	2.99[c]	10.7

[1] RTE cereal category examples: WG with added bran, for example, Quaker Oat Bran Cereal, Quaker Oats Company, Chicago, IL, USA; WG with no added bran, for example, Wheaties Cereal, General Mills, Inc., Golden Valley, MN, USA; non-WG with added bran, for example, Raisin Bran Cereal; non-WG with no added bran, for example, Corn Flakes Cereal.
[2] Values represent mean total dietary fiber intake as grams/day calculated using PROC SURVEYMEANS.
[3] Values represent the percentage daily contribution to total dietary fiber intake for all individuals and by WG intake group calculated using PROC SURVEYFREQ.
[4] Means for the same RTE cereal type (same row) with different letters ([a,b,c]) are significantly different ($P < .05$) according to ANOVA performed using SURVEYREG procedure.

study allowed for a better understanding of how consuming WG foods at different levels affects the proportion of total dietary fiber that is provided by various WG and non-WG food sources. This knowledge can inform the development of food-based dietary guidelines to facilitate increased fiber intakes.

The current study showed that breads and cereals were major food sources of WG in the diets of US children/adolescents and adults in 2009 to 2010 similar to the findings from NHANES data for the US population collected in 2001 to 2002 [13]. These 2 sources accounted for about two-thirds to three-fourths of WG intake in both periods. For children/adolescents, yeast breads were also the number 4 source of energy in the diet based on NHANES 2005 to 2006 data [34]. These findings indicate that yeast breads are commonly consumed by children/adolescents, making them an ideal food source of WG.

The updated assessment of WG intake completed in the current study from NHANES data 2009 to 2010 showed that mean daily WG intake for children and adolescents was similar to intake estimated from 1999 to 2004 NHANES data [9]. O'Neil et al [9] showed that the mean daily WG servings were 0.45, 0.59, and 0.63 oz eq/d for children and adolescents aged 2 to 5 years, 6 to 12 years, and 13 to 18 years, respectively. The current study (NHANES 2009-2010) showed that the mean daily intake was 0.57 oz eq/d. The mean number of WG servings for adults based on NHANES 1999 to 2004 ranged from 0.63 and 0.77 oz eq/d for adults 19 to 50 years and 51 years and older, respectively [10]. The current study showed that the mean intake was 0.82 oz eq/d for adults. Despite the media attention from the 2005 Dietary Guidelines calling for one-half of all grains to be consumed as WG and changes in the availability of products, intake is still at very low levels. Given the low current levels of WG and total dietary fiber intakes, and the positive relationship that exists between WG and dietary fiber intakes, increases in WG intake should be promoted for all US children/adolescents and adults.

One way to increase WG intake on a broad level is by making changes in regulations for federally funded meal and food supplement programs. The fourth School Nutrition Dietary Assessment Study conducted in 2009 to 2010 indicated that average National School Lunch Program (NSLP) lunches only provided 6% to 10% of recommended daily amounts of WG [35] for children/adolescents. The new school meal regulations requiring that whole grain–rich foods be served in the NSLP [36] may result in an increase in the daily amount of WG consumed over time among those who participate in the NSLP. Evidence for a potential increase in WG can be drawn from improvements in the availability and intake of WG foods for women and children participating in the Special Supplemental Nutrition Program for Women, Infants, and Children after new regulations were established to increase WG foods in Women, Infants, and Children food packages [37-39].

Ready-to-eat cereals are an important source of many vitamins and minerals, especially for children. On average, RTE cereals contribute 20% of folic acid and iron and more than 10% of B vitamins, vitamin A, and zinc while contributing

less than 4% of calories and total sugar in the diets of children 2–18 years of age [40]. In the current study, cooked and RTE cereals made substantial contributions to total dietary fiber, making up about 20% of the total dietary fiber intake for adults and children/adolescents. Several previous studies have shown that intake of RTE cereals among children and adolescents is related to greater total dietary fiber intake [41-43]. Analysis of secondary data from the National Growth and Health Study showed that as children age through adolescence, more frequent RTE cereal consumption was related to higher fiber intakes [42]. Cross-sectional data from a national Australian sample of 12- to 16-year-old boys showed that those consuming RTE cereals of all types had a higher total dietary fiber intake compared with those not eating RTE cereal [43]. Data from School Nutrition Dietary Assessment Study III (2004-2005) showed that RTE cereal consumption among school-aged children participating in the School Breakfast Program was related to higher WG intake [41].

Previous studies have not examined the contribution of different types of RTE cereals to fiber intake as in the current study. Whole grain and non-WG RTE cereals with no added bran provided the most total dietary fiber among all children and adolescents. The relationship between the total dietary fiber content of RTE WG cereals and top fiber sources was also examined by Williams and Felt-Gunderson [44] for adults completing a 14-day eating frequency diary. As expected, total dietary fiber intake was higher among a group consuming only WG cereals with at least 3 g of fiber per serving compared with a group consuming only WG cereals with less than 3 g per serving.

Ready-to-eat cereal types may vary considerably in WG and total dietary fiber content. The total dietary fiber content is readily available on Nutrition Facts Panels of RTE cereal packages to assist consumers in making healthful choices; however, labeling of WG RTE cereals for WG content is not always clear or consistent. In focus group interviews, parents and school food service personnel indicated that they read labels and look for fiber content when identifying WG foods in general [23,45,46]. Most of those interviewed lacked confidence in their ability to correctly identify WG foods. Results from another series of focus group interviews showed that consumers felt that they were unable to identify WG foods from an ingredient list [47]. These findings indicate that lack of knowledge and confidence in identifying WG foods may have a negative effect on WG intake of consumers as well as those involved in federal meal or supplemental food programs. The lack of knowledge of WG foods may also affect the accuracy with which individuals can report WG intake during dietary recall interviews and may offer a partial explanation for the low WG intake among children/adolescents and adults observed in the current study.

Limitations to the current study include the use of one 24-hour diet recall to estimate WG and fiber intake. Dietary intake accuracy based on 24-hour recalls is influenced by memory errors and could result in overreporting or underreporting of food intake especially among children and may not reflect usual intake. To improve accuracy of intake reports for children 6 to 11 years of age, proxy-assisted interviews were conducted, and for children 5 years or younger, proxy respondents reported intake data. Another limitation is the small number of children/adolescents (n = 83) and adults (n = 388) in the high WG intake group, respectively, which is reflective of the relatively low number of individuals who include these foods in their usual diet. The final limitation is that current databases may not be reflective of the marketplace, hence underestimating WG intake.

In summary, WG and total dietary fiber consumption remains well below the recommendations for most Americans [9-11], including both children/adolescents and adults. Consuming at least 3 oz eq/d WG helps ensure adequate consumption of total dietary fiber. Therefore, intake of WG foods, particularly WG RTE cereals, oatmeal, and yeast bread/rolls, should be encouraged to help Americans achieve both WG and total dietary fiber recommendations.

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